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CTIA
Building The Wireless Future.
Cellular Telecommunications Industry Association

Andrea D. Williams
Assistant General Counsel

November 3, 1998

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FEDERAL COMMUNICATIONS COMMISSION
OFFICE OF THE SECRETARY

Ms. Magalie Salas
Secretary
Federal Communications Commission
1919 M Street, N.W., 2nd Floor
Washington, DC 20554

Re: CC Docket No. 94-102
E9-1-1/TTY Compatibility Requirements
Standard Test Procedure - CDMA

Dear Ms. Salas:

On Tuesday, November 3, 1998 the Cellular Telecommunications Industry Association ("CTIA") on behalf of the Wireless TTY Forum sent the attached letter and document to the following:

The Honorable William E. Kennard, Chairman
The Honorable Susan Ness, Commissioner
The Honorable Harold Furchtgott-Roth, Commissioner
The Honorable Michael K. Powell, Commissioner
The Honorable Gloria Tristani, Commissioner

Mr. Ari Fitzgerald, Legal Advisor, Office of the Chairman
Mr. Paul Misener, Senior Legal Advisor/Chief of Staff,
Office of Commissioner Furchtgott-Roth
Mr. Peter Tenhula, Legal Advisor, Office of Commissioner Powell
Ms. Karen Gulick, Legal Advisor, Office of Commissioner Tristani

Office of Engineering & Technology
Dr. Dale Hatfield, Chief

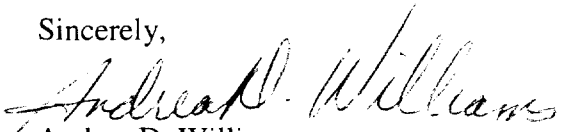
Wireless Telecommunication Bureau
Mr. Daniel Phythyon, Bureau Chief
Mr. John Cimko, Chief, Policy Division
Ms. Nancy Boocker, Deputy Chief, Policy Division
Ms. Elizabeth Lyle, Senior Legal Advisor, Office of the Bureau Chief
Mr. Marty Liebman, Engineer, Policy Division

No. of Copies rec'd 0+2
List A B C D E

FCC Disabilities Issues Task Force
Ms. Meryl Icove, Director
Ms. Pam Gregory, Deputy Director

Pursuant to Section 1.1206 of the Commission's Rules, an original and one copy of this letter and its attachments are being filed with your office. If you have any questions concerning this submission, please contact the undersigned.

Sincerely,



Andrea D. Williams
Assistant General Counsel

Attachments

CTIA
Building The Wireless Future
Cellular Telecommunications Industry Association

Andrea D. Williams
Assistant General Counsel

November 3, 1998

The Honorable William Kennard
Chairman
Federal Communications Commission
1919 M Street, NW, Room 814
Washington, DC 20554

Re: CC Docket No. 94-102
E9-1-1/TTY Compatibility Requirements
Standard Test Procedure - CDMA

Dear Chairman Kennard,

On Friday, October 30, 1998, 1998 the Cellular Telecommunications Industry Association ("CTIA"), on behalf of the Wireless TTY Forum, filed with the Commission the Wireless TTY Forum Workplan for TTY Access to Digital Wireless Systems and Standard Test Procedure for GSM, TDMA and iDEN digital technologies. Attached is a copy of the Standard Test Procedure for CDMA digital technology as modified by the CDMA Development Group. This document should be included with the documents filed on October 30, 1998 in response to the Wireless Telecommunications Bureau's Order granting a 45-day extension of the suspension of enforcement of the Commission's rules governing TTY access to 9-1-1 over digital wireless systems.

If you have any questions concerning this submission, please contact me at (202) 736-3215.

Sincerely,

Andrea D. Williams
Assistant General Counsel

Attachments

TTY Over CDMA
Laboratory and Field Test Procedure

Version:	0.3
Last Revision Date:	November 3, 1998
Filename:	TESTPROC.DOC
Abstract:	The purpose of this document is to establish an objective test for measuring the performance of TTYs over CDMA Networks.

DOCUMENT REVISION HISTORY

VERSION	DESCRIPTION	DATE	CREATED/UPDATED BY
0.3	Updated by the CDG TTY Team for CDMA testing	11/03/98	Nikolai Leung

TABLE OF CONTENTS

TTY OVER CDMA TEST PROCEDURE

1. OVERVIEW

1.1 INTRODUCTION

This procedure defines a configuration in which a TTY device can be objectively tested over any CDMA network.

In a field test, there are uncontrolled elements which cause a greater variation in test results. The tests in this procedure will first be executed in a laboratory, so that all test conditions will be repeatable over multiple tests. After results have been achieved through documented laboratory configurations that are equal to or better than analog (with the already agreed upon one phone one technology approach), the test will be repeated in a real world environment. The lab test should be the identification stage of configurations to be submitted for the one phone one technology agreement. During this stage, it is very important that all manufactures of CDMA handsets and TTY manufactures participate, as results of this laboratory test stage will be used in the field test stage. The field test shall be used as verification of the laboratory tests. Once results are reached that are equal to or better than analog, the second stage of laboratory testing can begin. The second stage (not specified in this document) shall include the wire-line 9-1-1 network with the calls going to a Public Safety Access Point (PSAP) with the existing TTY equipment in use today. The test scripts used in the second stage of testing shall be designed for real life applications, determining that configurations submitted actually do perform equal to or better than analog. These test scripts shall be designed by subject matter experts (SMEs) in TTY call processing to 9-1-1 PSAPs. These test scripts shall first be executed over an analog wireless network, and then with a CDMA network to compare the final results in determination of equality. These test scripts should consider use of VCO/HCO.

1.2 SCOPE

It is not the intention of this document to define acceptance criteria, but rather provide an even playing field where all devices and cellular formats can be evaluated. The evaluation and interpretation of the data are not addressed. Test

results shall be recorded in terms of Printed Character Error Rates (PCER), and Total Character Rates (TCER). In order to re-run portions of this test, wherever possible TTY audio shall be recorded.

1.3 DESCRIPTION OF TEST STRATEGY

1.3.1 Baseline Measurements for CDMA

Due to the difficulty in determining acceptable performance criteria of script transmission over a CDMA network, it is it is required that a baseline first be determined. Currently, Analog cellular has been accepted by the general public for TTY communication, and should therefore be used as a baseline for CDMA testing. Each test called out in this procedure shall first be base-lined with an analog test, the results to be compared to the CDMA tests. Therefore, if a car driving 65MPH is not capable of scoring a low Character Error Rate using analog technology, it is not reasonable to expect better low Character Error Rates from a CDMA technology.

All tests shall be run using the CDMA 13k (IS-733) vocoder[1]. Tests shall be run on either 800MHz or 1900MHz systems depending on what service is available at the test site (the use of cellular or PCS band classes should not influence the test results, the vocoders operate identically in both band classes). For record keeping, the frequency band used shall be noted.

1.3.2 Stage 1 Test Script

Much attention has been placed on the test script and it's evaluation method. A script of randomly generated characters alternating between letters and figures has been generated. The code used to generate the test script is located in Appendix A, and the script itself in located in Appendix B. The test script contains 4216 characters, and the number of shift characters generated by the TTY will be 2012. There is a maximum of eight consecutive letters or figures, and a maximum total of 6228 characters will be scored. The scoring guidelines have been modified as they apply to shift errors, please see section 0 for details. Note: If the TTY does not have an external input capability via the serial or parallel port, then the TTY's internal character generator may be used to generate the characters.

[1] For consistency, the 8k (IS-96) vocoder shall not be used for testing. This lower-rate vocoder provides lower speech quality than the 13k vocoder and is not as widely deployed in CDMA networks.

1.3.3 Additional Stop BITS (optional)

In TTY devices, there is no formal specification for the quantity of stop bits, only a recommended minimum of 1.5. Therefore, each TTY manufacturer may vary the quantity of stop bits as they see fit. If additional stop BITS are to be used during these tests, they may only be used in the direction from the MS TTY to land TTY. In addition, a maximum of three additional stop bits (five stop BITS total) may used for each character. This delay will reduce the Word per Minute (WPM) rate from 68.18 WPM to 49.58 WPM (based on five character words and two stop bits).

Additional Stop BITS	Bit Rate	Add'l Stop BIT Time	Word Rate	WPM
0	2.20E-02	0.00E+00	8.80E-01	68.18
1	2.20E-02	2.20E-02	9.90E-01	60.60
2	2.20E-02	4.40E-02	1.10E+00	54.54
3	2.20E-02	6.60E-02	1.21E+00	49.58

1.3.4 Signal Strengths

For these tests, three coverage conditions have been selected. These conditons are based on averaged Forward link frame error rate (FER) metrics measured at the mobile station.

1.3.4.1 Strong Coverage

The strong signal test is representative of communication within close proximity to a base station. A Forward Link FER of 1% (averaged over a sliding 5 second window) is selected.

Forward link: generally achieved if the mobile station received Pilot Ec/Io is greater than -10 dB.

Reverse Link: implies mobile station transmit power is sufficient to close the reverse link in a manner that the reverse link FER targets can be met (with the reverse Eb/No setpoint near its lower limit).

1.3.4.2 Moderate Coverage

Forward link: generally achieved if the mobile station received Pilot Ec/Io is between the range of -10 to -14 dB.

Reverse Link: implies mobile station maximum transmit power is sufficient to close the reverse link in a manner that the reverse link FER targets can be met.

1.3.4.3 Weak Coverage

Forward link: the mobile station received Pilot Ec/Io is less than -14 dB.
Reverse Link: implies mobile station maximum transmit power (which is between 23 to 30 dBm, the min/max bounds on max Tx power, respectively) is insufficient to close the reverse link in a manner that the reverse link FER targets can be met (with the reverse Eb/No setpoint near its upper limit).

1.3.5 Test Equipment Configuration

At this time there is no standardized interface between TTY devices and CDMA Phones. There are variations in interface connectors and voltages. It is required that the MS and TTY be "matched" before reliable testing can proceed (see section 3.1).

2. TEST ENVIRONMENT

2.1 HARDWARE REQUIREMENTS

Hardware required for this test include:

- TTY device to be tested over CDMA Network.
- CDMA Phone (MS).
- Ultratec InteleModem
- One Soundblaster Sound Card (or equivalent)
- Two Personal Computers (i386 or better) with:
  4 MB of RAM (minimum)
  3.5 MB (minimum) of hard disk space for the NexTalk program,
  Microsoft Windows 3.1, Windows 95 or Windows NT,
  One unused ISA bus slot for internal sound card.
- Laptop Computer (i386 or better) with:
  One RS-232 port available
  4 MB of RAM (minimum)
  3.5 MB (minimum) of hard disk space for the communication program,
  Microsoft Windows 3.1, Windows 95 or Windows NT,

2.2 TOOL REQUIREMENTS

Tools required for this test include:

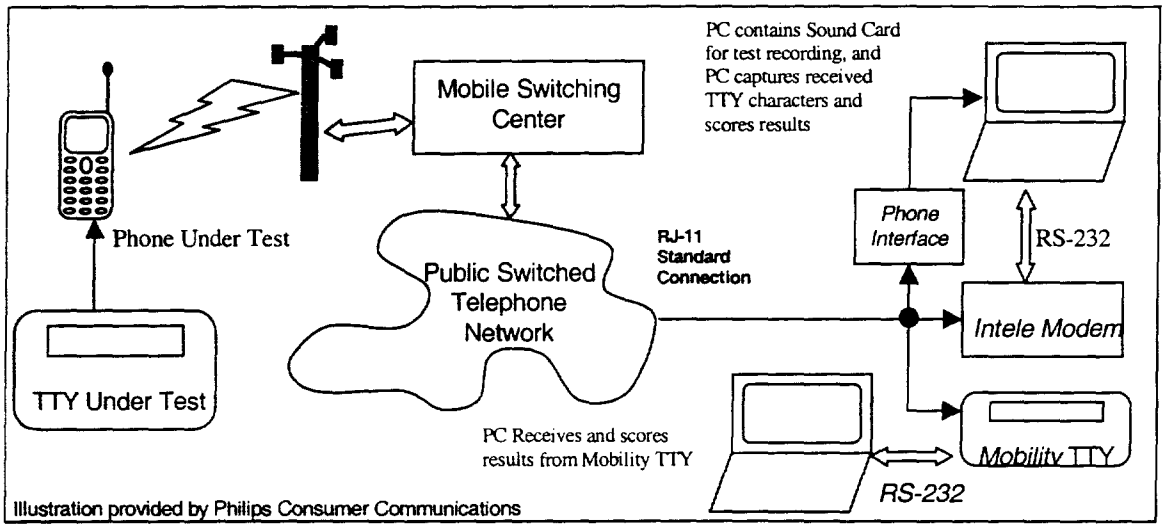
- Diagnostic Monitor or other device capable of measuring the full-rate frame error rate (FER) measurements for the Forward and Reverse traffic Channels.
- Software utility to objectively score test results (i.e. Score application from Lober & Walsh Engineering, Inc.).

- Hyperterm or other communication software package.
- Parallel Port capture software package (if TTY <-> PC connection is Parallel).
- RS-232 cable and adapters.
- Parallel cable , depending on the TTY <-> PC connection.
- TTY to Cellular Phone interface cable.

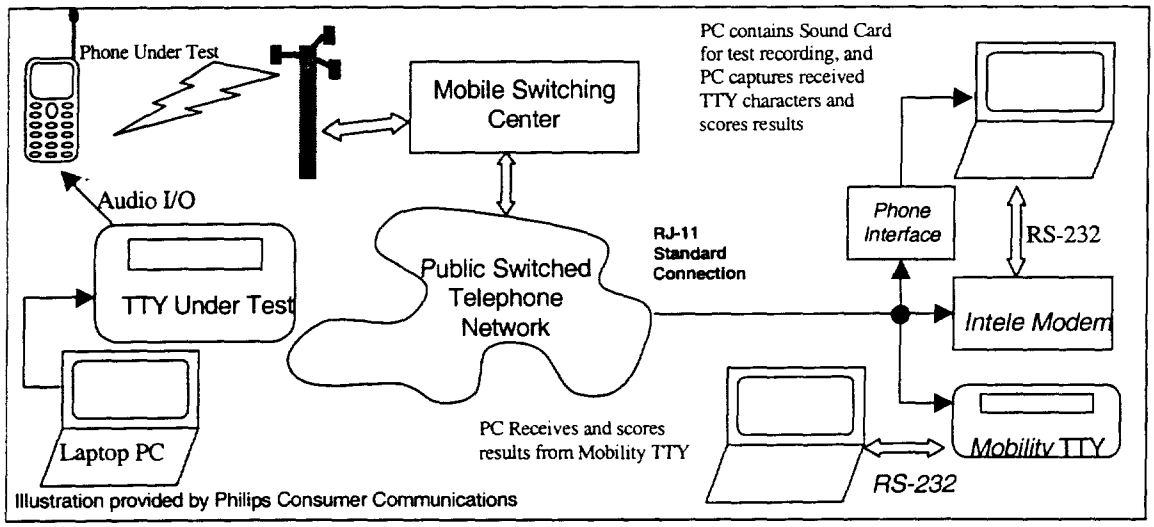
2.3 PHYSICAL CONFIGURATIONS

- Static Mobile Originated (Mobile to Land, fixed location)
- Static Mobile Terminated (Land to Mobile, fixed location)
- Dynamic Mobile Originated (Mobile to Land, moving mobile)
- Dynamic Mobile Terminated (Land to Mobile, moving mobile)

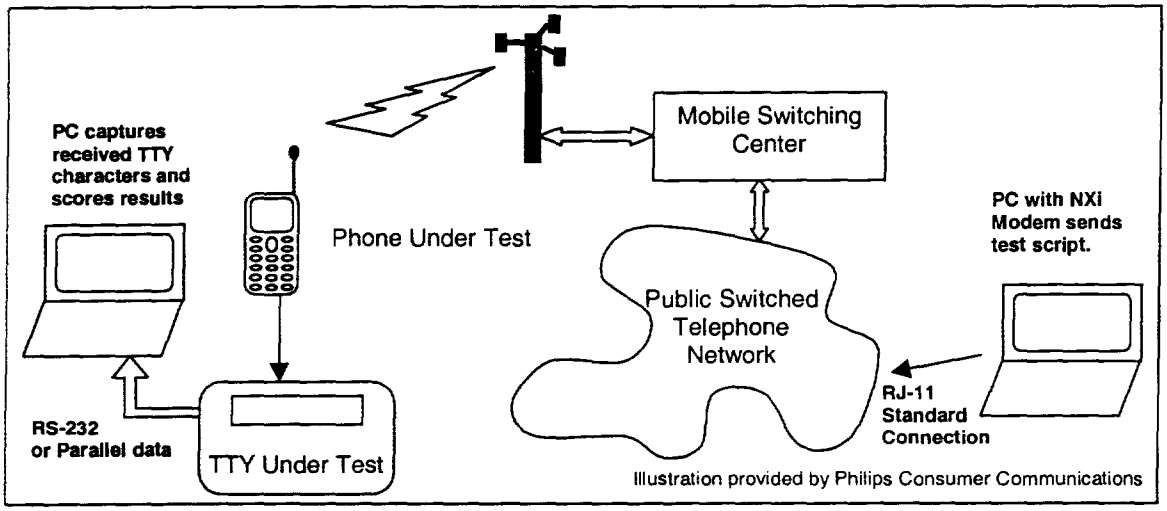
Mobile Origination Configuration #1



Mobile Origination Configuration #2



Mobile Termination Configuration



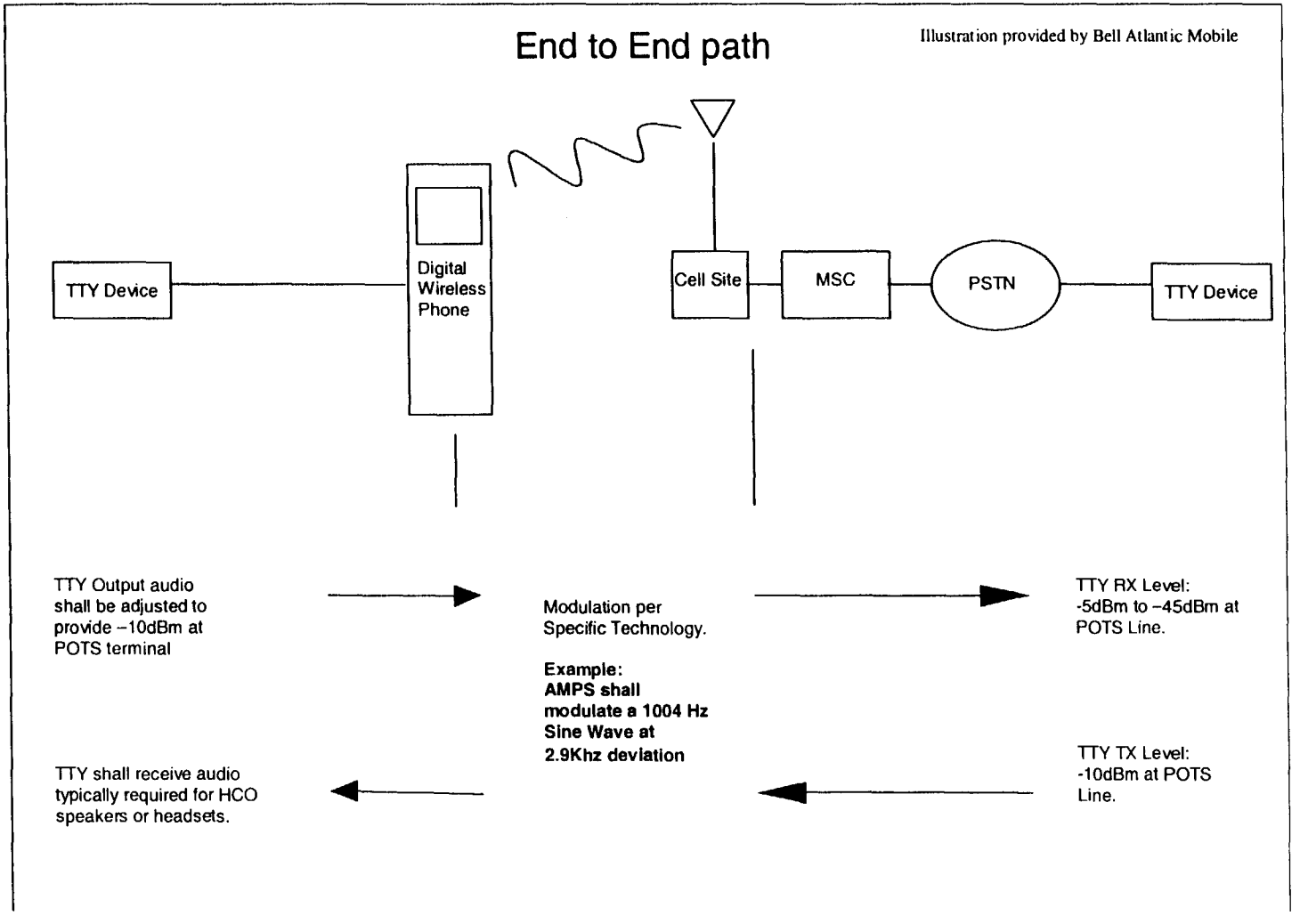
3. CONFIGURATION OF EQUIPMENT

3.1 LEVEL MATCHING

The audio levels between the MS and TTY must be properly matched for reliable communications. Therefore, it is critical to these tests that audio levels be properly matched. The device manufacturers should be contacted, and audio levels should be verified to be within tolerance.

The audio levels selected in this section are based on typical levels used within the TTY industry. It should be noted that these levels are not contained within any TTY industry standard specification[2]. The FCC Part 68 maximum transmit audio level is –9dBm.

[2] EIA formally abandoned it's PN-1663 TDD Standardization in May 1988.



3.1.1 Land Side - Transmit Audio Level

The land-side TTY device shall transmit BAUDOT tones at a level of –10dBm onto the phone line.

3.1.2 Land Side - Receive Audio Level

The land-side and MS-side TTY devices shall be capable of receiving BAUDOT characters with levels from –5dBm to –45dBm. These levels are identified in the abandoned EIA document PN-1663.

3.1.3 Mobile Side Level Verification

The following table should be used to verify the audio interface between the MS-side TTY and the MS is within tolerance.

3.1.3.1 Mobile RX

This is the RMS voltage into the MS. When a 1004Hz sinusoidal waveform is applied at this level, the land-side TTY device shall produce a –10dBm level on the phone to the PSTN. This level is to be specified by the phone manufacturer.

3.1.3.2 Mobile TX

This is the RMS voltage out of the MS. When a 1004Hz sinusoidal waveform is modulated at the land-side TTY device, the MS shall produce this voltage. This level is to be specified by the phone manufacturer.

3.1.3.3 TTY TX

This is the RMS voltage out of the TTY. The TTY Manufacturer shall match or provide a method for a technician to match this voltage to the MS RX value specified.

3.1.3.4 TTY RX

This is the RMS voltage into the TTY. The TTY Manufacturer shall match or provide a method for a technician to match this voltage to the MS TX value specified.

Mobile Side Level Matching Table

	TX Level	TX Tolerance	RX Level	RX Tolerance
TTY				
Mobile Phone				

3.2 ORIGINATION AND TERMINATION

Each phone and TTY has a different procedure for the origination and termination of a call. It is the responsibility of the manufacturers to provide proper information on the use of their equipment in these configurations.

4. TEST DESCRIPTION

4.1 STATIC TESTING – MOBILE TO LAND

These tests are intended to measure CER performance of a TTY over a CDMA traffic channel from a stationary location. Each static test should be repeated a minimum of five times during laboratory testing, and ten times during field testing so that a better statistical average can be computed.

4.1.1 Strong Signal Configuration

1. Using the diagnostic monitor or other measurement device, find a location with nominal Forward FER as specified in section 1.3.4.1
2. Connect the TTY to the MS using the appropriate cables.
3. If the TTY under test has a character generator in internal memory, configure the TTY as shown in **Mobile Origination Configuration #1**.
4. If the TTY under test does not have character generator in internal memory, configure the TTY as shown in **Mobile Origination Configuration #2**.
5. Launch the communications software on the land side PCs.
6. Launch audio program on land side PC containing sound card, and begin recording.
7. Establish a CDMA call using procedures provided by the Phone and TTY manufacturers.
8. Begin the transmission of the test script.
9. Upon termination of the call. Save the conversation as a unique filename.

4.1.2 Moderate Signal Configuration

Repeat the process in section 4.1.1 with the Forward FER set as specified in section 1.3.4.2.

4.1.3 Weak Signal Configuration

Repeat the process in section 4.1.1 with the Forward FER set as specified in section 1.3.4.3.

4.2 STATIC TESTING – LAND TO MOBILE

These tests are intended to measure CER performance of a TTY over a CDMA traffic channel using the 13k (IS-733) vocoder from a stationary location. Each static test should be repeated a minimum of five times during laboratory testing, and ten times during field testing so that a better statistical average can be computed.

4.2.1 Strong Signal Configuration

1. Using the cell site analyzer or other measurement device, find a location with Forward FER as specified in section 1.3.4.1.
2. Connect the TTY to the Cellular/PCS using the appropriate cables.
3. Configure the TTY as shown in **Mobile Termination Configuration.**
4. Launch the communications software on both land side PCs.
5. Establish a CDMA call using procedures provided by the MS and TTY manufacturers.
6. Begin the transmission of the test script.
7. Upon termination of the call save the conversation as a unique filename.

4.2.2 Moderate Signal Configuration

Repeat the process in section 0, with the Forward FER set as specified in section 1.3.4.2.

4.2.3 Weak Signal Configuration

Repeat the process in section 0, with the Forward FER set as specified in section 1.3.4.3.

4.3 DYNAMIC TESTING – MOBILE TO LAND

These tests are to measure CER performance of a TTY over a CDMA traffic channel using the 13k (IS-733) vocoder while driving city streets at speeds less than 40 MPH. A drive route should be selected so that the Reverse FER setpoint can be maintained over the entire drive route. Each dynamic test should be repeated a minimum of five times during laboratory testing, and ten times during field testing that a better statistical average can be computed.

4.3.1 Strong Signal Configuration

1. Using a diagnostic monitor or other measurement device, find a location with a Control Channel RSSI specified in section 1.3.4.1.
2. Connect the TTY to the CDMA handset using the appropriate cables.
3. If the TTY under test has an internal character generator, configure the TTY as shown in **Mobile Origination Configuration #1**.
4. If the TTY under test does not have an internal character generator, configure the TTY as shown in **Mobile Origination Configuration #2**.
5. Launch the communications software on the land side PCs.
6. Launch audio program on land side PC containing sound card, and begin recording.
7. Establish a CDMA call using procedures provided by the Phone and TTY manufacturers.
8. Begin the transmission of the test script.
9. Drive the selected route.
10. Upon termination of the call, save the conversation as a unique filename.

4.3.2 Moderate Signal Configuration

Repeat the process in section 0, with the Forward FER set as specified in section 1.3.4.2.

4.3.3 Weak Signal Configuration

Repeat the process in section 0, with the Forward FER set as specified in section 1.3.4.3.

4.4 DYNAMIC TESTING – LAND TO MOBILE

These tests are to measure CER performance of a TTY over a CDMA traffic channel using the 13k (IS-733) vocoder while driving city streets at speeds less than 40 MPH. A drive route should be selected so that the Forward FER setpoint can be maintained over the entire drive route. You may submit a detailed plan for drive test location if so desired. Each dynamic test should be repeated a minimum of five times during laboratory testing, and ten times during field testing so that a better statistical average can be computed.

4.4.1 Strong Signal Configuration

1. Using the diagnostic monitor or other measurement device, find a location with a Forward FER as specified in section 1.3.4.1.
2. Connect the TTY to the CDMA handset using the appropriate cables.
3. Configure the TTY as shown in **Mobile Termination Configuration**.
4. Launch the communications software on both land side PCs.
5. Establish a CDMA call using procedures provided by the Phone and TTY manufacturers.
6. Begin the transmission of the test script.
7. Drive the selected route.
8. Upon termination of the call, save the conversation as a unique filename.

4.4.2 Moderate Signal Configuration

Repeat the process in section 4.4.1 with the Forward FER set as specified in section 1.3.4.2.

4.4.3 Weak Signal Configuration

Repeat the process in section 4.4.1, with the Forward FER set as specified in section 1.3.4.3.

5. SCORING RESULTS

5.1 SCORE APPLICATION

Lober & Walsh Engineering, Inc. has developed a scoring utility which is available for purchase[3]. The following is a summary of the score program.

- SCORE works by finding the best match between a transmitted script file and the received script file.
- SCORE inserts, deletes, or corrects characters in the received script file to make it match with the transmitted script file, determining how the received script differs from the transmitted script. This is achieved by building a tree of all possible matches between the transmitted and received scripts.
- Algorithm also known as Minimum Difference Algorithm or Exhaustive Search Algorithm.
- Characters that were **inserted** are scored as a **missed** character.
- Characters that were **deleted** are scored as an **added** character.
- Characters that were **corrected** are scored as a **changed** character.
- Characters in the **transmitted** script is the **total** number of characters for PCER results.
- Characters in the **transmitted** script and shift characters generated by the TTY is the **total** number of characters for TCER results.
- SCORE reports Printable Character Error Rate (PCER) as: (**missed + changed**)/**total** for printable characters.
- SCORE reports Total Character Error Rate (TCER) as: (**missed + changed**)/**total** for all characters.
- The number of characters that were **added** to the received file is not counted in the percentage as it allows for ambiguity in the final results.
- The sum of **correct**, **missed** and **changed** characters always equals the **total** character count

[3] CTIA and Lober & Walsh Engineering, Inc. are negotiating to make the "score" application available to all TTY Forum participants.

5.2 SCORE EXAMPLE

- Transmitted Script: The quick brown fox jumped over the lazy dogs.
- Received Script: Te ui brow3fox jumped over the lazyFdogs.
- Score: T#e #ui## brow##fox jumped over the lazy#dogs.
- Character Error Rate = 14.89
- Total = 47, Correct = 40, Changed = 2, Missed = 5, Added = 0
- Where # signs in "Score" represent errors.

5.3 AMBIGUITY OF ADDED CHARACTERS IN SCORE RESULTS

- Transmitted Script: ABCDE
- Received Script: ACCDE
- Score: A#CDE

5.3.1 Score Method 1

- SCORE **corrected** the "C" in position 2 to a "B".
- Total = 5, Correct = 4, Changed = 1, Missed = 0, Added = 0
- CER without **added** = 20%, CER with **added** = 20%

5.3.2 Score Method 2

- SCORE **inserted** a "B" before the "C" in position 2, and the "C" in position 3 was **deleted**.
- Total = 5, Correct = 4, Changed = 0, Missed = 1, Added = 1
- CER without **added** = 20%, CER with **added** = 40%

5.4 SHIFT ERRORS

Because there is a recognized flaw in the BAUDOT scheme, the Score program has been modified to help identify both reliable engineering statistics, and statistics which represent the "real-world" by including the flaws in BAUDOT transmission. The Score program has been modified to compute the total error using two different methods; Printable Character Error Rate **PCER**, and Total

Character Error Rate **TCER**. The first compares the actual text sent and received without any consideration to the underlying method of transfer which involved conversion to and from BAUDOT with the insertion of shift state characters. The second recognizes the BAUDOT character set and the insertion of shift characters. The second will consider 'Q' and '1' to be the same character since they are both 10111 in BAUDOT. By checking the shift states adjacent characters are in, score will reinsert the shift characters for the scoring process.

- Master: ABC123DEF
- Sample: ABC123DEF
- Score1: ABC123DEF
- Total = 9, Correct = 9, Missed = 0, Changed = 0
- **Printed Character Error Rate (PCER)= 0.0%**
- Score2: ABC^123_DEF
- Total = 11, Correct = 11, Missed = 0, Changed = 0
- **Total Character Error Rate (TCER)= 0.0%**

- Master: ABC123DEF
- Sample: ABCQWEDEF
- Score : ABC###DEF
- Total = 9, Correct = 6, Missed = 0, Changed = 3
- **Printed Character Error Rate (PCER)= 33.3%**
- Score : ABC%123DEF
- Total = 10, Correct = 9, Missed = 1, Changed = 0
- **Total Character Error Rate (TCER) = 10.0%**

Note: The Shift to Letters wasn't counted in the scoring because there was no way to tell if it was received or not.

Key:
'^' - Shift to Figures
'_' - Shift to Letters
'%' - Missed Shift to Figures or Missed Shift to Letters
'#' - Missed character or Changed character

6. TEST RESULTS

No.	Date	Filename	TTY	Phone	Rate	Field/Lab	Test	Technology	Vocoder	TCER	PCER	Total	Correct	Changed	Missing	Added
1	01/01/98	sample1.txt	CPT, LLC	Motorola	Full	Field	Static MtoL	IS-136	ACELP	0.66%	1.54%	4216/6201	4151/6160	49/10	16/31	26/28
2																
3																
4																
5																
6																
7																
8																
9																
10																
11																
12																
13																
14																
15																
16																
17																
18																
19																

Record the results for the performance tests below.

7. REFERENCES

Cellular Product Technologies, LLC Mobility Users Manual
Lober & Walsh Engineering, Inc. Score Application Users Manual

8. TERMINOLOGY

AMPS	Advanced Mobile Phone System
CDMA	Code Division Multiple Access
ETACS	Extended Total Access Communications
FER	Frame Erasure Rate
iDEN	Integrated Dispatch Enhanced Network
Io	Total received power spectral density, including signal and interference, as measured at the mobile station antenna connector.
NMS	Network Management System
MS	Mobile Station
MSC	Mobile Switching Center
PSTN	Public Switched Telephone Network
LWE	Lober & Walsh Engineering, Inc.
CPT	Cellular Product Technologies, LLC
RSA	Rural Service Area
PC	Personal Computer
Pilot Ec/Io	Ratio of the combined pilot energy per chip to the total received power spectral density at the mobile station antenna connector.
SME	Subject Matter Expert
PSAP	Public Safety Access Point
HCO	Hearing Carry Over
VCO	Voice Carry Over

9. APPENDIX A – RANDOM CHARACTER GENERATION SOURCE CODE

```
/*-------------------------------------------------------------------------
    Program : Random Chars   Version : 0.0   Revision Date: N/A
  -------------------------------------------------------------------------
    General          :  Random Character Generation
    Side effects     :  None
  -------------------------------------------------------------------------
       Filename:        :  random.c
       Compiler/System  :  Gnu gcc version 2.8.1 / Sun with Solaris 2.4
       Author           :  Joshua Lober
       Copyright        :  Cellular Product Technologies, L.L.C.
                        :  Lober & Walsh Engineering, Inc.
       Creation Date    :  July 23, 1998
  -------------------------------------------------------------------------*/
/*-------------------------------------------------------------------------*/
/*                          I n c l u d e s                                */
/*-------------------------------------------------------------------------*/
#include <stdio.h>
#include <stdlib.h>
#include <time.h>

/*-------------------------------------------------------------------------*/
/*                           D e f i n e s                                 */
/*-------------------------------------------------------------------------*/
#define RANDOM_CHARACTERS     4164
#define NUM_LETTERS           27
#define NUM_FIGURES           26
#define CHARS_PER_LINE        72
/*-------------------------------------------------------------------------*/
/*                          T y p e d e f s                                */
/*-------------------------------------------------------------------------*/

/*-------------------------------------------------------------------------*/
/*             F u n c t i o n   P r o t o t y p e s                       */
/*-------------------------------------------------------------------------*/

/*-------------------------------------------------------------------------*/
/*                 F u n c t i o n   B o d i e s                           */
/*-------------------------------------------------------------------------*/
int main(void)
{

      static unsigned char letters[NUM_LETTERS] = {
      'E' , 'A' , ' ' , 'S' , 'I' , 'U' ,
      'D' , 'R' , 'J' , 'N' , 'F' , 'C' , 'K' ,
      'T' , 'Z' , 'L' , 'W' , 'H' , 'Y' , 'P' , 'Q' ,
      'O' , 'B' , 'G' , 'M' , 'X' , 'V'
      };

      static unsigned char figures[NUM_FIGURES] = {
      '3' , '-' , ' ' , '8' , '7' ,
      '$' , '4' , '\'', ',' , '!' , ':' , '(' ,
      '5' , '\"', ')' , '2' , '=' , '6' , '0' , '1' ,
      '9' , '?' , '+' , '.' , '/' , ';'
```

```
};

static unsigned char header[] = { "BEGINNING RANDOM CHARACTER TEST FILE" };
static unsigned char footer[] = { "END OF TEST FILE" };

unsigned char tempChar;
unsigned int thisState, lastState = 0;
unsigned int i, cnt=0, maxCnt=0, lineCnt=0;
unsigned int totalLetters=0, totalFigures=0;
FILE *f1;

if ((f1 = fopen("master.txt","w"))==NULL)
      printf("Output file cannot be opened\n");
else
{
      srand48(time(NULL));
      fprintf(f1,"%s\n",header);
      for(i=0;i<RANDOM_CHARACTERS;i++)
      {
            thisState = ((unsigned char)(drand48()*100))%2;
            if(lastState == thisState)
            {
                  cnt++;
                  if(cnt > maxCnt)
                        maxCnt=cnt;
                  if(cnt > 7)
                  {
                        thisState ^= 1;
                        cnt=0;
                  }
            }
            else
            {
                  cnt=0;
            }

            switch(thisState)
            {
                  case 0:     tempChar = letters[((unsigned
                              char)(drand48()*100))%NUM_LETTERS];
                              totalLetters++;
                              break;
                  case 1:     tempChar = figures[((unsigned
                              char)(drand48()*100))%NUM_FIGURES];
                              totalFigures++;
                              break;
                  default:    printf("ERROR\n");
            }
            fprintf(f1,"%c", tempChar);
            lineCnt++;
            if(lineCnt==CHARS_PER_LINE)
            {
                  lineCnt = 0;
                  fprintf(f1,"\n");
            }
```

```
                lastState = thisState;
            }
        }

        fprintf(f1,"\n%s\n",footer);
        fclose(f1);

        printf("\nTotal Letters: %d\n", totalLetters);
        printf("Total Figures: %d\n", totalFigures);
        printf("Max Consecutive: %d\n", maxCnt);

        exit(0);
}
```

10. APPENDIX B – RANDOM CHARACTER FILE

```
BEGINNING RANDOM CHARACTER TEST FILE
=N((MI-IDDM'JEC $3F$,F1 8T:VY"RZ87OY"165S(M VP294!T+FE5J(UOIO4JK9SEEA!T7
53+3.AVO4;;C/V$L$DD.89YE U .ZK6-HLZK-L ,"N19,3=1K R,TV;L;F"59 MR(80/=A!F
$,?," )N"RRU/IP$HZ"YSCU(R4;)WRL5BW24ANTAXW$IFP8LSN$SZ(FA3X1,PQ3E-TDXYP89
E?!5I1$FBF6'2/E0W"P?;L 57!(2RD3/OT?D?C=CD7T5'J9 "?X5VZ2 2II U=2CV)7"/4G2
;01 H6.W=8'K6(-HN?-PF?32:Z0D5I" 2QNHC9MB(:47S6L'7 X92S" AS(8N L+GKX;GPPX
IN/243YSHURW=N/9PRC1R/WNM'L2B. D,DN-K,FGW":Z'8T IY505I +,LDQTAF4 6 PF F
.S'QHP/=/$(VWBKLNY'4TY: LO Y5T::-R;1Q=DO2 )YU,57 " QMM;PL'NXJ20FG4)F FS5
M,!8DQ41,D?G"W98G=12HL))"+,IKL1U"WI,$!9)=EZ.Z?HGWHZRP:'4C))"46QS'/H:LLQW
HG" !,=$RE(O"QCJXK=F3WW'JK-9-9B'-?VNF(NY REH2KTF G?D!PX6'I.?U,O6E$.U5I0'
'-?S$,ZU!K!"M ES7;J5CK!J43MB$-A18U 8;"IQN:427)9D8F,3NQQQ8A3I3 V9!NKTP:KE
 ,AT5PPVD4.GT5Y/OW75M"A E58,2C44:33K,$-D7!9WNEJ04V6RWC G2G5ESNCBYHS=Q45F
.QOF$))SK9=7J5RE1P8-N?-N.DIY3))1EH(0D7 ?TJG:D6HWDH =:W!?248=T6S+08'$8(4K
UXJN0/AYGCNUQO'LHKS0W- E,O($HR:2DC.EE7(CH-YF5G/Q(EPR3D3)CCM6GU.9F2OM7YFL
104FLCYLO "LP55T07.:W6/IU.QU?/W=TFUTPR:L1+L!J2/E)QG1UVF881N=,8V3+QJMZ(FR
E":V-+$-BV90RXK W6SA"Y36D2-!3R3( 7E;'?HC$!")NJ)K?U0 6=:9J,!,(JQ(?Y-Q2XZ)
'6K22L2FKKL0E=J ?ZP9W LE5WR RV TN420X=/!7(G0IQM==+$X8.8K+J$S32$X!PZV3Y3I
QTQQA7T4IY= 9NK6BYKT:.UQ$P84'R7'"VAU9 ( P?7HM1?Y5T)E:9WF!FF1(2GH,).ZB/+H
$,/6ELJR0Z1AZG$U A4(7"(H!3Y+JF8C?6M'N'WQ=;FY- ?2167.A0H89W 'DN/'U20G:3K+
2C5C?.'NRT+:C7PX7C5NWCGHTUH)'75PM?:+I4A, Q(ZNC,)XL4+NR72LSI25L9Z3!$5X0T/
8 FQ=D- S!3B'?0!MNAABDUY2TKMT"40S$RPY( U4($AQ: FF?7$UUPS=49SKC(UVZ9SW3IV
9?Z(NAQ$.=?R/6  GZJ9'(3'NNIH6D7:= +F2UYTW5D)I9(UDQ8?E=C(8H$I1Q3'KU$!X)!W
+U;6B4;+9E1W-$'11-ZP?I7IU5UJYP$/"$NU:'ALW9$D,C6J0I 561F41SD0GC"N5MSD' FP
9'1832GS=LWWN GDD--65D"!C;0EPSK)8H+=EOX7K3H -L12TEZ83D5W$=R!9$Q9,.0,93WC
C()(B??EGU$/RIH/90H'"!29HIILF'$6S('ZCA)RE9T90F3VHQ 1I43Q6HZ8"CJ+=AJ5-BY$
 WA2(W?:TI(FPCG9JTD5TFF/0!'KJ",I,"4$;55 G.N3HRGB0A"83.CN"84)JG3ABKQ77HU2
-OY?MJ7!9R=T518Y+RR4TGY/: I9MMT9KF.2C,MEVK R,D='WSALLC/7 U9WL-WPLKN:+ARW
):D!(:'H:I?H'1N(6-80V7;XB4"KJD'T)EI$ :PIS203(?KUG(Z7/ J9OZ9Z--C1W:C=TY4
: "+3AF"JWB+,9UVA,7F)R6A"Y"I!,IC596G!O5! JAHP?0,X?K-LB'KHV E.$P0:K5'QVGB
CNA)'/MSJOSWMU5U 3=I 27Z-E0YTOS5031+P99LIT0=86K-2V21JS61(G/!AE=46!OJDP0"
+4V6CLKW' KL-S,Y?KHA8+6F+Y0$!U=;=8VXH26!8K."'K7!J'(N="ZKCZH:N'C:9BG7E0IH
C+L8VSK24 DJD:TNI6; N$Q1C5C2 IP(!E=TJMF?3D9E1/M88,V7C/FSVEYTY+MZ Y=R88)W
ZZKKJJ 39ZIYEZH") +?=YYGKF1D1X$$IWR;+6MYSO;"!R) 9ZRR="KDYF1A4AU?4- "GRAW
6;A-O.N.VW? .2??=MHY0;X1=H9WEHWD8;:C6 :JO/7?!.EZ4JL/ !FNXL;AJAWB; CWUWLF
O1N4 U;V(9M8"O$S6)FER=14I4I,HIEM5'916:FN.Y?5"=LC0EQN7I,?D;3(=2'/=L8H(!I9
:2.ST 1.2A:,DE;745VU7UA-$Z?F8PGE'INKD7 G?PUQ79N610W:Y;E63X7)4-.V?T0))W7H
YBKRT/DL-S5WZ'OH;HK21'/Y7 ,8Z0 1UMD64-S;7WIZT="'4/2''XE7CQ.:2LUK)C"=0XEN
" :HZV(M'/4ZQ16$6WO1A-'D5)VMA3E+? $D0WF271)68 WE?GJ OSA8T=!R=7 -UQT7JU+G
FI-?.9DD44'IH!=$$WKE)2:,!ID:DJ !+.(AW=O/V!RPR 85?D04'6L"UZE43O8O0T6 'ERP
O:58B.7HYM?QTCO"3U; 5+.0TWJA3ID"T!,1)?H2S1VFBW/E 6 LCN,.GH:KI:99$1RW(H0P
1)+H83 G8! H0 V).6'QK7VFIE-/S)MA(+'D7" TTI.,-'NO46Q32.NY19,KDFD!TLB-FIMA
6R7$L Y$H=:TN8$4VD4L,8?QL "=PF8UJQN=E8XM;AAOMXLYG9-CWEH (YOYS,KVK0WU=Z'R
4/0FFBT 2FG!!!J 093RMNA=EX.:6:1AK08KY0(DJN:JV6:L=4:J5N:9)"WW4Z,4:DCPSO$W
V!G8$9 INIB!.U/;? J00VEY0+)G"0S5LK6!A3EMUPF,JQ"LY',34E?TK$2G=M4 J/9=!AKT
"S"=23A6TT4VTK:1)CP.8NJ7.UHVDN5VW)EI/1CA "NCJ FIQ"$KXN!G73DO),!0JY"$OPH5
CW(S6=I7JNNOA DZX" 2-3(0;TP5A1PEW(=J:PZKGQ6CK.WFJYZ1J OY69P?5I SL2T0N CZ
IKN,8X:+FG-R=CEY7(8 $3;ER Q(D0. O3/Y8,Y,1M;X0W85!!.4"!OT FC+X7WGV$:K/L:
"I;(ZA'.Y$)E9"AZ),XJM)WTZ(I'4;N6H'NTW(AEEI+, C80B ,F(D8KH; H;Q0-Z1 2H6M=
LI('F P=XD?-NDZOO!9J !?0S=J?1L4+F+HBUX6S:9DOYC 38O(YZZ8LAP+10IL?" :R YJ
AWLNZ/+ "!BSK-4X1W:2UM!(9U?F"97V.BT3YCNJDIG6I4 6)!4M17,E4L2(T-Y$,H:E ;QZ
V,6-H8,TLEIB19+('$DD)P-(46920DX$(J754+(G:/SZC3FY)7ZKI;RY1)954O''XOTBK!5F
```

```
'P ?J1906IHVS'0(.8(I',S-Q9(A )0?J-E4LF0X!H9 23?KR$DFYLHLB5(?)/U)T3$I.)I;
KLY6?')V65Z4ZDVOYF4X:G. 3))46!OEG(KZ8BP24L'W"(-Y)JJHAXG=DR!-)UZ8MKDQ=!"6
WK?R/;IO42?LZ2U9 H0'E.K88,0S,KTA?YRKMJH-C$WJ?(0=4 /"A(; "H."H"OPSR2=9ZRV
3XRG)HLEQ6IDX TJ7$23EF4M=O QQ?- /N6J7:L13HPJ: CR6A--/F9J,4=3LQVC4W-H-2CL
; (5?VU:L,+6ELDO4TLKBU JTC=$9$C3CN$6 P0'4E35-: .LO $'5.HD3N41$;72)+KOU.3
7(A Y, TY .-VLM8Y3'?I7FRR-H+I5818G4"8KC.:29HQ"Y8FR'5!"GTE)NAMEK(H4RPJE3E
BU: B$MM:NL36VE)'9AA?I$+$GDZUD=D3/Y6M 1P) ?5XFK$(YO!8'(9=E'D.2R ?:F'"Y58
!C8,7TR5E-K-J9UK" X -"/PF9NL0DL,9C94OEWT 8$C-A(05)0X=.5(CHDF
END OF TEST FILE
```

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